Climate Information System for Agriculture and Water Resource Management in the Southeast USA

Progress Report for SECC within the NOAA RISA Program January – December 2008

Introduction

The Southeastern Climate Consortium (SECC) conducts research to reduce climate and weather risks to agriculture and natural resources in Alabama, Georgia, and Florida and cooperates with the Extension Service and other agencies to provide relevant, useful climate information to stakeholders in agriculture, forestry, and water resource management.

This work plan for Jan – Dec 2009 is being submitted by the Univ. Miami, which manages the cooperative agreement with NOAA for the SECC members (Univ. Miami, Univ. Florida, Florida State Univ., Univ. Georgia and Univ. Alabama-Huntsville). Auburn Univ. is also members of the SECC and will be receiving funds this year for the first time through a coping with drought proposal. In addition, North Carolina State University has joined the Southeast Climate Consortium, but does not receive RISA funds and avoids research topics that are being conducted by the Carolinas RISA. For completeness, we also include here the work plan for SECC member Florida State Univ., although they now receive their RISA grant funds administratively through their NOAA-sponsored Applied Research Center.

The overarching goal of the SECC is to develop a climate information and decision support system for the southeastern USA that will contribute to an improved quality of life, increased profitability, decreased economic risks, and more ecologically sustainable management of agriculture, forestry and water resources.

CIMAS Research Theme: Theme 4: Human Interactions with the Environment

Link to NOAA Strategic Plan Goals: NOAA Mission Goal 2: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond. NOAA Mission Goal 3: Serve Society's Needs for Weather and Water Information. Strategy: To develop generic tools for the production and dissemination of relevant climate information (diagnostic and forecasts); to strengthen decision making in agriculture.

Toward our overarching goal we have established six objectives. As a multi-institutional consortium, different member institutions of the SECC emphasize project objectives that build on the strengths of each institution.

1. To develop downscaled ENSO climate information and forecasts for the Southeastern USA. (Florida State Univ. and Univ. of Florida)
2. To enhance and extend agricultural applications of climate forecasts in the Southeastern USA. (Univ. Miami, Univ. Florida, Univ. Georgia, Univ. Alabama-Huntsville)
3. To develop and refine methods to incorporate climate forecast in water resource management in the Southeastern USA. (Univ. Florida, Florida State Univ., Univ. Georgia, Auburn Univ., and Univ. of Alabama-Huntsville)

4. To develop new and improved methods for integrating models from different disciplines for application of climate forecast information in agricultural and water resource decision making. (Univ. Miami, Univ. Florida)
5. To foster effective use of climate information and predictions in forestry and wildfire management. (Florida State Univ.)
6. To document and assess the utility and impact of climate forecast information provided to stakeholders in agriculture and water resource management. (Univ. Miami, Univ. Georgia)

The Strategic Plan of the SECC is designed so that activities toward meeting these objectives complement activities funded through other sources. For example, with funding from the USDA, SECC scientists at the Univ. Georgia work closely with Univ. Miami scientists to evaluate stakeholder information needs and to assess SECC products, thereby complementing RISA supported activities toward objective 6.

Our activities continue to emphasize collaboration among research in the SECC and partnership with Extension. Such partnerships ensure that our findings and products are relevant in different states, and to the extent possible, in different agricultural systems.

Since the establishment of *AgClimate* in the fall 2004 as an internet-based decision support system for the use of climate information in agriculture, we have devoted a major part of our research and extension effort toward developing and providing more climate information through *AgClimate*. In 2008, as part of our effort to transfer *AgClimate* to Extension, we changed the name to *Agro*Climate [http://AgroClimate.org]. The transition is nearly complete, though the SECC continues to provide new information and tools as well as updating databases and otherwise helping to keep the website fresh.

In 2006 we began to strengthen our efforts in our Water Resources Management and plan to continue this effort in 2008. Based on the lessons learned in the development of *Agro*Climate we have begun development of a new prototype web site, Southeast Water Climate, which will provide a decision support system for water resource managers.

With additional funding through the NOAA program on “Coping with Drought,” in 2008 we conducted a project in collaboration with CLIMAS to implement a version of *AgroClimate* in New Mexico. The initial phase of this project is complete. This program also provided support to a symposium that SECC is co-hosted with the Univ. Florida in June 2008, CIMR – Climate Information for Managing Risks, Partnerships and Solutions for Agriculture and Natural Resources Managers.

The current work plan includes two new projects funded through the “Coping with Drought” program, namely the development of a open-source *Agro*Climate (UF, FSU, UGA) and the development of drought management tools for municipal water managers (AU, UGA, UF).

What follows is an integrated plan of work, based on our strategic plan. Collaboration among institutions is paramount to the success of the SECC so we require all activities to be conducted in collaboration though a single institution generally leads each of the activities.

Research Activities

In addition to planning activities that focus on specific objectives, a significant effort will involve coordination across institutions and states in the SECC. The SECC Coordinator, Keith Ingram, provides leadership in integrating our program, and Clyde Fraisse is our liaison with Extension. Each spends time in coordinating our work with Extension and the SECC members working in other institutions (FSU, UGA, UAH, UM, and NCSU).

Activity C.1. Communication and Liaison. The Coordinator organized regular meetings of the SECC Executive Committee, generally through tele-video conference. The Coordinator organized an annual program review of SECC scientists held in Gainesville, FL in May 2008 and a planning meeting held in conjunction with a WMO expert panel in Orlando, FL in October 2008. In addition, the Coordinator arranged an SECC delegation to visit various federal agencies in November 2008, including USDA Risk Management Agency, USDA CSREES, NOAA Climate Test Bed, the US Climate Change Science Program, and NOAA Climate Program Office. The Coordinator served as liaison to funding agencies, other RISAs, and related organizations to assure timely flow of information and represented the SECC at workshops, conferences, and other meetings.

Activity C.2. Partnerships. The Coordinator assisted SECC members in the establishment of several new partnerships. In 2008 we began collaborations with two NGOs that represent socially disadvantaged farmers, the Federation of Southern Cooperatives, which is based in Atlanta, GA, and the North South Institute, which is based in Davie, FL. In addition, we are developing partnerships with the Pacific Island RISA and WMO on the use of *AgroClimate* and applications of climate information for managing risks.

Activity C.3. Managing Complementary Activities with Different Funding Sources. With 7 universities and 5 program areas, the Coordinator and other members of the Executive Committee have led the development of the SECC Strategic Plan, which guides collaboration and programs activities. In 2008 North Carolina State University joined the SECC through the project funded by USDA CSREES. NCSU will develop *AgroClimate* for their state, but will not receive RISA funds are careful to avoid redundancy with activities of the Carolinas RISA.

In 2007, we began research on a new topic, climate change, which has been incorporated into our plans of work and emphasizes the development of local and regional scenarios that will be used by the various SECC programs.

Activity C.4. Coordination of Extension activities. In 2007, the University of Florida created a tenure-track Climate Extension Specialist position in the Institute of Food and Agricultural Sciences that will be converted to state funding after 2010, which has been filled by Clyde Fraisse, who has led the SECC extension effort since 2003. The SECC Extension Team includes: two climate extension specialists, extension specialist in economics and crop production, and three state climatologists, with evaluation and assessment support from three anthropologists and one natural resources economist, and overall support from the SECC Coordinator.

Activity C.5. Climate Information for Managing Risk. The SECC and UF co-hosting a symposium entitled Climate Information for Managing Risks – Partnerships and Solutions for Agriculture and Natural Resources Managers. The symposium had about 200 participants. The final report, presentations, and photos are available on-line at the symposium web-site [http://conferences.ifas.ufl.edu/CIMR/]. Jim Jones chaired the organizing committee and Keith Ingram was co-chair.

Objective 1. Develop downscaled ENSO climate information and forecasts for Florida, Georgia, and other Southeast States.

Historically, the Florida State University has been the lead institution in the acquisition and analysis of historical climate data, research on climate variability in the Southeast U.S., dynamic climate modeling, and the production of climate forecast information for incorporation in decision support systems, which target the end user. The climate program works closely with SECC assessment program (Objective 6) to ensure that products, information, and education efforts meet the needs and provide value to the end user. User feedback often provides the impetus for new directions in basic climate research.

Activity 1: Dynamical Crop Modeling

In order to explore the feasibility of using the CFS model output to help determine crop yields in the southeast a series of experiments were performed using the CFS model data. Because the CFS data is available at 2.5° resolution a statistical downscaling technique was performed in order to obtain the CFS data on the 20km regional grid. For this experiment, only the CFS model precipitation was used. It was supplemented with the observed surface max/min temperatures and surface solar radiation in order to drive the DSSAT crop model over Tifton, GA. Warm season (March through September) simulations were performed for the 19-year period (1987-2005) to characterized the crop yields.

There is considerable dry seed yield variability with the years: 1989, 1991, 1994 and 2005 having the most yields. The variability in the precipitation between the years is not significantly large. This indicates that the yields simulated by the dynamic crop model were highly sensitive to wet/dry spell sequences during the growing season. Not only increasing persistence of wet/dry day occurrences was important, but the timing within the growing season when these dry/wet spells occurred was especially important. For example, during the tasseling period of crop growth, the most critical period for producing maize, a lack of precipitation or high water stress translated into low yields. After the grain-filling phase, water stress did not play an important role in determining the yields. This makes the intraseasonal forecast of precipitation especially important in determining seasonal crop yields. Also note that the CFS model tends to over predict precipitation by almost 500 mm/season for each of the 19-years. By applying a bias correction to the precipitation we were better able to match the observations. Although seasonal means only tell half of the story. We have begun to examine the intraseasonal characteristics of the precipitation as simulated by the CFS model.

In addition, we are currently developing a 1-way/2-way crop-atmospheric coupling using the COAPS regional model and the DSSAT crop model over the southeast U.S. with collaboration from the University of Florida. Up to recently, the DSSAT crop models were only applied to specific locations to determine crop yields. The crop model is now being expanded and assigned to each of the 20km downscaled grid points in the southeast U.S. Feedbacks will initially be only one way, that is, the atmosphere forces the crop and the crop doesn't feed back to the atmosphere. Within this year, 2-way full coupling will be available.

Activity 2: Statistical Downscaling using the CFS model data

CFS seasonally predicted precipitation at a resolution of 2.5° is statistically downscaled to a fine spatial scale of ~20km over the southeast United States. This study is motivated by the need for regional climate information for crop growing seasons in the southeastern U.S. The downscaling is, therefore, conducted for March through August, when the very localized precipitation prediction has been very challenging. The present work is part of ongoing downscaling research preceded by Lim et al. (2007), which dealt with surface temperature under the support by NOAA/ARC.

We obtain the global model precipitation for downscaling from the National Center for Environmental Prediction / Climate Forecast System (NCEP/CFS) retrospective forecasts (Saha et al. 2006). Ten member integration data with time-lagged initial conditions centered on mid- or late February each year are used for downscaling covering the period of 1987 to 2005. The observed precipitation used for statistical training is obtained from the National Weather Service Cooperative Weather Stations (NWS/CWS) [http://www.nws.noaa.gov/climate/]. The gridded CWS data (20km×20km) (daily) for the southeast US is provided by the Florida Climate Center [http://www.coaps.fsu.edu/climate_center/].

Activity 3: Update, expand, and automate climate database operations

Historical weather data is critical to all aspects of this project and provides the basis for all climate information used in the decision support tools, including the wildfire risk forecast. In addition, the historical weather data drives the crop development models whose output is used in peanut, tomato, and potato decision aids. The historical weather data must have a long period (at least 50 years) of relatively homogeneous records and must have a spatial resolution fine enough to reveal detailed climate information at the county level for the states of Florida, Georgia, and Alabama.

The preparation of a historical weather observation database for the Southeast is complete. The weather observations are compiled from the National Weather Service's Cooperative Observer network (NCDC TD 3200) and contain daily values of maximum temperature, minimum temperature, and precipitation for a period of record of at least 50 years extending through December of 2004. The stations are selected based on 1) length of record, 2) data completeness, 3) homogeneity, and 4) representativeness to surrounding agricultural areas. The state climate offices in Florida, Georgia, and Alabama rely on their local expertise and familiarity with the coop network in making the station selections. The final data set contains historical weather records from 92 stations in Florida, 64 stations in Georgia, and 58 stations in Alabama.

The raw weather observations and the bootstrapped "synthetic" climate data describe the first level of the SECC database structure, and these data are used both in operations and in research. For operational use in driving the climate decision support tool on *AgroClimate*, the data have also been transferred into secondary and tertiary levels using MySQL database server. The secondary level simply mirrors the information found in the primary level, only stored as MySQL data tables and housed on the dedicated SECC server which supports *AgroClimate*. The tertiary level of climate data has been condensed into information which is passed directly to the climate tool for display in *AgroClimate* in response to user queries.

In order to provide the most current information possible, the historical climate data must be updated periodically. The initial data gathering was done in 2003 by manually downloading the data from servers at the National Climatic Data Center (NCDC). We are currently updating the climate data to include all of 2008 and the manual process has proven cumbersome and time consuming, especially when translating the data to the secondary and tertiary levels. The ability to automate and streamline this update process has become apparent and critical to the future of this project. FSU has been working with the Southeast Regional Climate Center personnel to facilitate the daily transmission of NWS automated weather station and cooperative observer observations to FSU for further processing and quality control. An automated update process would not only provide the most current information, but allow us to refine some climate and crop-related products to include near-real time climate events and processes. This is especially important to accumulated climate forecast products where initial conditions are important, such as the chill units, growing degree days, and the Keetch-Byram Drought Index (KBDI) forecast tools available on *AgroClimate.*

In conjunction with automating the database updates, we find it beneficial to include weather observations from our partners with the agricultural weather networks in the Southeast, specifically the Florida Automated Weather Network (FAWN) and the Georgia Automated Environmental Monitoring Network (GAEMN). The inclusion of these networks is the first step in making near real-time monitoring and adjustment of seasonal forecasts in accumulating quantities, such as chill units and growing degree-days.

Activity 5: Modified JMA ENSO index

In previous landmark studies on ENSO variability in the Southeast, COAPS used a sea surface temperature based index developed by the Japanese Meteorological Agency (JMA Index) to classify historic weather observations by ENSO phase. In these studies, the concept of an "ENSO year" was developed where October through the following September would all be designated as one phase, depending on the phase during the northern hemisphere winter season (Sittel, 1994). Until recently, this same approach has been used in most ENSO related climate studies undertaken by the SECC.

A closer examination of individual ENSO events showed some similarities in seasonality (peak SST anomalies in the winter months), but often striking differences in the timing of onset or cessation of warm and cold events. In particular, ENSO phase would often change as early as the spring or summer months. The concept of the "ENSO year" did not fit well with observations and severely limited the ability to identify ENSO related climate impacts at these times of year.

In an effort to rectify these problems in the timing of ENSO events and to glean more information on potential climate impacts during the warm or growing season, COAPS modified out approach to ENSO phase classification using the JMA index. In this new approach, called "modified JMA", we keep the criteria that the index must remain above the 0.5 degree threshold for at least 6 consecutive months to classify as an El Niño even (-0.5 for La Niña). However, nstead of using the concept of an "ENSO year", phase is classified on a month by month basis with a warm or cold event beginning only when the index reaches the 0.5 degree threshold and ending as soon as the anomalies fall back below 0.5 degrees. (FSU, UGA, UF)

Activity 6: Long-term trends and climate change

The first step in preparing for a changing climate system is a thorough understanding of the past climate. A careful analysis of historical weather and ocean observations reveals useful information on the average state and variability along with changes on time scales from seasonal, to interannual (1-5 years), decadal, and even long-term trends. As described above, much is known about the year-to-year variations as caused by the El Niño/La Niña cycle in the Pacific Ocean. There are also variations on time scales from 10-50 years, such as the known warm periods around 1950 and 2000 and the cold winters of the 1980's. Warm season precipitation has dropped 10% to 15% in recent decades around central and south Florida, whether caused by land use changes or by circulation changes in the Atlantic Ocean. Many Florida weather stations also exhibit long term trends in temperature and rainfall, whether caused by a changing global climate or by local changes in land use and urbanization.

Further analysis of long-term weather records (80 to over 100 years) from National Weather Service cooperative observers also shows a coherent pattern of multi-decadal cycles in daily maximum and minimum temperatures across the region. This variability is characterized by relatively warm decades in the 1930's and 1950's and cold period from around 1960 through 1990. Superimposed on this region wide signal in the record are influences of land use changes such as the heavy urbanization and draining of wetlands in Southeast Florida and the conversion of the Everglades into agricultural lands south of Lake Okeechobee. Multi-decadal variations are also seen in temperature extremes, with clusters of severe freezes bringing fundamental changes to the citrus industry and other agriculture.

Activity 7: Variability of extremes and extreme events

Studies have shown that very limited benefit exists in climate forecasts focused on shifts of temperature or precipitation near the mean or climatological average. The greatest benefit of climate information lies in the forecast of extremes, events near the tails of the historical probability distribution. Further research is needed that addresses the likelihood of such extremes, whether it be torrential rainfall, drought, freezes, or severe weather.

The El Nino-Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), the Pacific Decadal Oscillation (PDO), and the Polar Vortex Oscillation (PVO) produce conditions favorable for monthly extreme temperatures and precipitation. These climate modes produce upper level teleconnection patterns that favor regional droughts, floods, heat waves, and cold spells, and these extremes impact agriculture, energy, forestry, and transportation. The above sectors prefer the knowledge of the worst (and sometimes the best) case scenarios.

Activity 8: Development of numerical tools for the analysis of climatic time series.

Several numerical tools were developed in the last few years to provide a common platform the systematic, reproducible, statistical analysis of hydro-climatic data. These tools consist in a series of libraries of functions (packages) written in Python, a powerful, open-source, platform-independent scripting language. These packages are based on Numpy and Scipy, two libraries for scientific and engineering computing considered the de facto standard for the manipulation of multidimensional arrays in Python.

At the core of these tools is a reimplementation of the way series with missing data are handled in Numpy. Our modifications have been officially part of Numpy since version 1.0.5. The current version is 1.2.2 and takes many bugs fixes into account. Another release is planned for early 2009. (1.0.5). A second series of modules has been developed for the manipulation of time-indexed datasets and is also readily available as a specific Scipy package (scikits.timeseries). This package can be downloaded at http://pytseries.sourceforge.net/.

Activity 9: Lead-time climate and weather data forecasting

Some of our activities focused on using pattern recognition for any possibility of lead time forecasting of realization of daily weather data consisting of precipitation, maximum and minimum temperature and solar radiation. An algorithm for daily weather data series prediction based on the k-NN approach was developed.

To test our algorithm of pattern recognition we used 10 different sites across the state of Georgia. This approach was verified across the world for 16 different sites, with at least one site from each continent.

Objective 2: Enhance and extend agricultural applications of climate forecasts in Florida, Georgia, and other SE states.

Activity 2.1. Climate Change

Extension activities related to climate change during 2008 included the development and implementation of a climate change In-service training to Extension faculty during the 2008 IFAS Extension Symposium. The topics covered during the symposium were:

1. Basics of Climate Change
2. Effects on coastal marine ecosystems & services:
3. Response of crops, vegetables, and forages to anticipated rise in carbon dioxide and temperature
4. Potential impacts on pests and diseases

5. Carbon sequestration and quantification aspects applied to forestry
6. Carbon markets and trading

The presentations are available online at: http://pdec.ifas.ufl.edu/symposium/2008/

In addition, a new UF-IFAS focus group area has been created under the Florida Environment main goal area with the objective of coordinating Extension activities related to climate variability and change across the state. (C. Fraisse)

Activity 2.2 AgroClimate enhancement

The main accomplishments related to *Agro*Climate during 2008 were the redesign of the system (Figure 1) and addition/enhancement of several components:

- ENSO phase forecast for the next 3 months is now displayed in the home page;
- Inclusion of basic climate change information as related to the Southeast U.S.
- Periodical release of climate and agricultural outlooks;
- Addition of monthly climate summaries for the states of Florida, Georgia, and North Carolina;
- Translation of most components to Spanish in preparation for the launching of a Spanish version of *Agro*Climate targeting Hispanic growers;
- Increased integration with state weather networks in Florida and Georgia to provide in-season updates of cumulative variables such as chill accumulation and growing degree days;
- Improved freeze probability maps have been developed and added to *Agro*Climate.

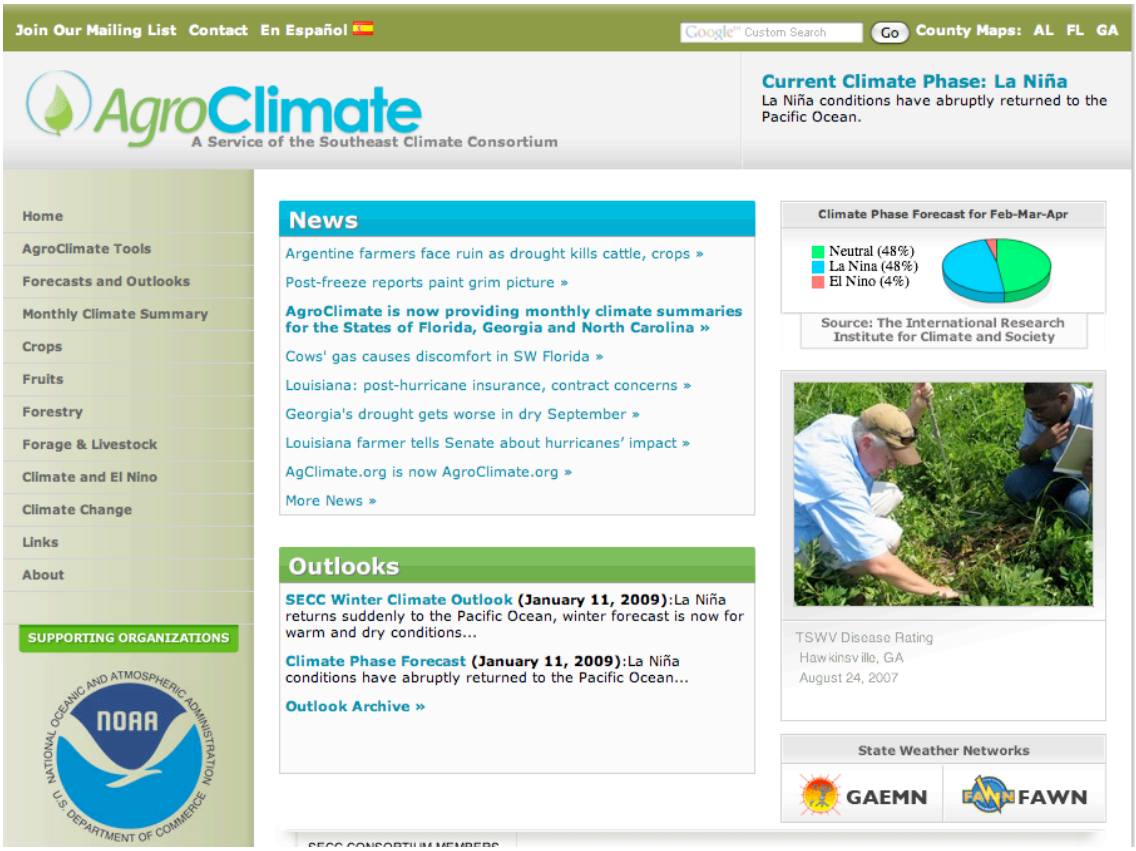

Fig. 1. A new layout was developed and implemented in 2008.

Enhanced cooperation with state weather networks resulted into the improvement of the AgroClimate chill accumulation tool to include by-weekly updates of chill accumulation observed at weather stations belonging to the Florida Automated Weather Network (FAWN) and Georgia's Automated Environmental Monitoring Network (AEMN). Observed accumulation is updated by-weekly and seasonal chill accumulation is predicted taking into account current levels of accumulation observed at FAWN or AEMN stations (Figure 3). Chill accumulation is calculated based on the number of hours below 45°F, 32-45°F and also in terms of chill units for several temperate fruits such as peach, blueberry, and strawberry. (C. Fraisse)

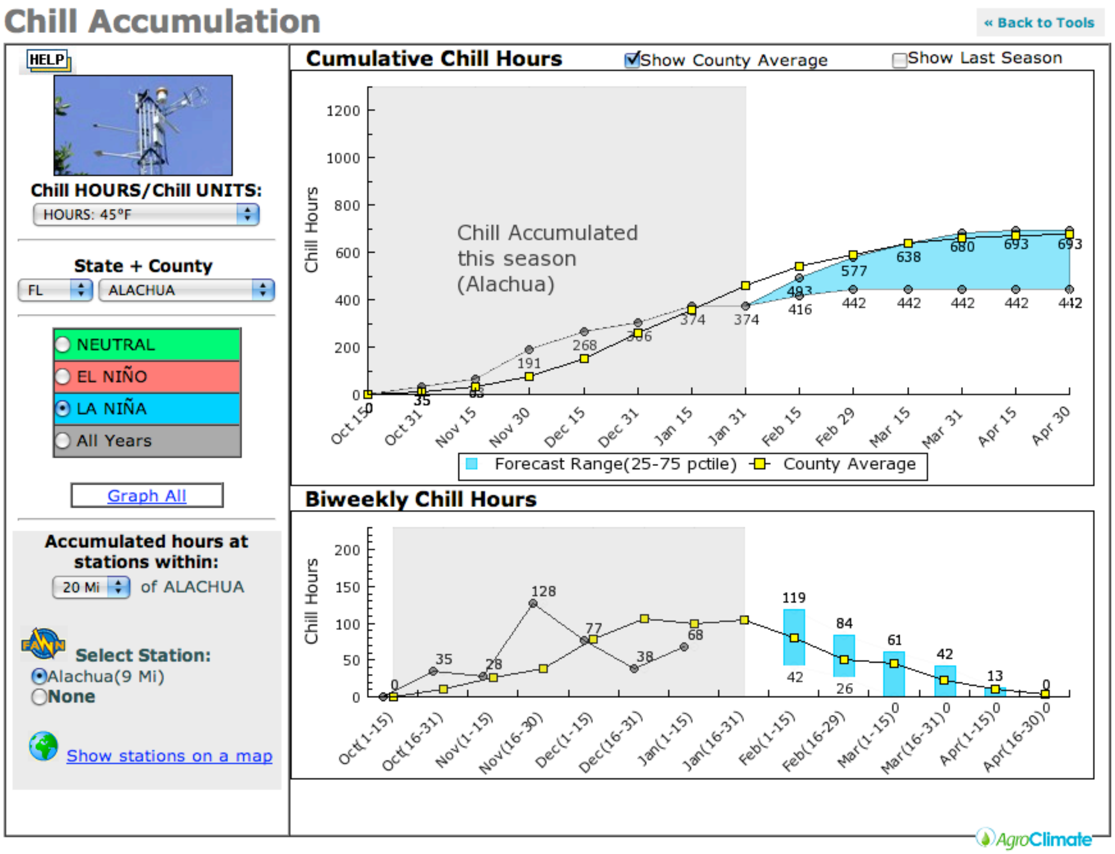

Fig. 2. AgroClimate chill accumulation tool showing total and by-weekly accumulation (<45° F) observed at the FAWN Alachua weather station. The graphs also indicate the forecast for the remaining of the season.

Activity 2.3. Transfer of AgroClimate to New Mexico

During 2008 we collaborated with *Climas* in a project that aims to reduce the drought vulnerability of New Mexico's urban agricultural sector through the development of an urban agricultural component for the AgroClimate decision-support tool. The AgroClimate urban landscape drought module provides realistic estimates of urban landscape water budgets and potential water savings under different outdoor water management strategies. A climate needs assessment, administered to New Mexico Extension agents and specialists, revealed a 62% likelihood that urban agriculturists would use climate information to aid decisions. Furthermore, 76% of the agents believe that information on urban agriculture and home horticulture is highly relevant to their county. In the first part of our project, a pilot study in Las Cruces, New Mexico, we have classified urban landscapes into distinct types, based on quantitative factors such as percentage lawn area and the ratio of softscape (e.g., trees and shrubs) to hardscape (e.g., pavement and patios). We will use climate information to estimate urban landscape water budgets for the different landscape types and estimate landscape performance under changing drought scenarios. These data form the backbone for an AgroClimate map interface that allows users to identify their neighborhood and landscape type. Some custom adjustments can be made for time of year, and other required factors. Drought water budget and landscape performance calculations can be tied to urban drought plans. Our goal is to implement this tool during 2009 in cooperation with *Climas* and the New Mexico Cooperative Extension Service. Key stakeholders include the New Mexico Water Task Force, the New Mexico Drought Task Force, and urban homeowners and horticulturalists. (C. Fraisse, C. Roncoli)

Activity 2.4. Economic modeling of climate information use in the context of farm programs (David Letson and Daniel Solís)

Can climate information raise farm incomes? To answer this important question, farm risk models must evaluate climate information in a context where farm programs matter.

David Letson and Daniel Solís have introduced a framework of studying the value of the climate information under federal farm programs in the SE USA. This framework integrates climate, biophysical, economic and policy components in a comprehensive optimization and simulation model to study the impacts of government intervention in the use of ENSO-based climate forecast.

This research is aimed to influence users' decision or government policy making in order to improve economic well being and to reduce risk. A pilot study has been starting in Northwest Florida including selected farm programs.

Using this framework to study the value of the climate information, a new framework to strategize crop insurance options has also been developed and is in process of improvement. Other similar projects are in trial development.

Most recently we have expanded the research scope to include a wider range of risk management approaches, more farm enterprises, more farm programs, and other locations. Also, the model framework has been adapted to respond new research questions in collaboration with extension agents and other stakeholders.

Activity 2.5: Agricultural Outlooks

Climate and commodity outlooks were developed in close collaboration with different SECC members and University of Georgia (UGA) Research and Extension Faculty. These outlooks were disseminated in various media forms and outlets to stakeholders including county agents and growers. A significant outcome was the increased visibility of the climate extension program as a result of extension specialists and county agents developing their recommendations (e.g. peanut, cotton, turfgrass management) based on the impacts of climate forecasts.

Activity 2.6 Simulated yield

The CSM-CROPGRO-Maize and CSM-CROPGRO-Cotton models were run for all counties producing both crops in the three states. The counties were selected on those who produced these crops during the period from 1975 to 2006 as reported by USDA-NASS.

Activity 2.7 Pests and Diseases

We examined the effects of El Niño-Southern Oscillation (ENSO) on the prevalence of tomato spotted wilt virus (TSWV) in peanut, and how a weather-based component can be integrated with the current TSWV risk index. The goal was to develop a tool to assist peanut growers in effectively managing spotted wilt disease. Analyses of the five-year TSWV survey dataset (1998, 1999, 2002, 2004 and 2005) showed a varying level of interactions between the ENSO phases and different components of spotted wilt risk index. The results indicate that the severity of spotted wilt in peanut was consistently lower in a La Niña compared to an El Niño or a Neutral year. TSWV severity during a Neutral phase was lower than in an El Niño year, but the differences were not significant. Deviation from the mean severity during different ENSO phases showed a similar trend, with lower than average severity during La Niña years. There were significant interactions between ENSO phases and the individual risk index component. The available data indicate that climate played a significant role in spotted wilt severity of peanut. Climate might indirectly affect spotted wilt severity through varying weather patterns and weather parameters, including temperature and cumulative rainfall. In addition to the risk index component, the average daily air temperature in April, the mean daily minimum air temperature in March and April, the number of rain/wet days in March, total rainfall for April, and the amount of water balance (rainfall minus evapotranspiration) for April, provided significant contributions in predicting the severity of spotted wilt in peanut. A nonlinear regression analysis of the interaction between TSWV risk index point (excluding herbicide and plant population) and wet or rainy days in March showed an additive effect of the two variables on spotted wilt severity.

Objective 3: Develop and refine methods to incorporate climate forecasts in water resource management in Florida, Georgia and surrounding states

Activity 3.1. Use of seasonal climate forecasts to reduce risk in regional water supply management

The relationship of seasonal sea surface temperatures (SSTs) in the Atlantic and Pacific Oceans with county corn yields in Alabama, Florida, and Georgia was evaluated for the period 1970-2005 using singular value decomposition (SVD) analysis and confirmed using principle component analysis (PCA). Using a Monte Carlo approach, field-significant results were found between SSTs and yields in the July-September (JAS-1) and October-December (OND-1) seasons in the previous year and with the January-March (JFM) season of the current. Based on the results found by SVD analysis and confirmed by PCA, indices of spatially averaged SSTs in regions of the north Pacific and Atlantic Oceans were derived. Using theses indices along with the Niño3.4 index, cross-validated multiple linear regression models were developed to predict the first principal component of corn yield residuals using index values in the JAS-1 and OND-1 seasons. The results of the regression models indicate that the indices of SSTs show significant predictability with corn yield residuals at substantial lead times. Using the cross-validated models 69.6% and 76.0% of county corn yield residuals were statistically significant with seasonal index values in the JAS-1 and OND-1 seasons, respectively. (C. Martinez, J. Jones)

Activity 3.2: ***Developing and implementing a prototype methodology for incorporating seasonal climate forecasts for use in Tampa Bay Water hydrologic modeling***

Tampa Bay Water uses a variety of hydrologic and statistical models as part of their effort at risk-based management of short- and intermediate-term operations and long-term planning. In support of effective water resource management and efficient groundwater/surface water rotation of intermediate-term operations, 1-month to 1-year seasonal forecasts are currently being developed using historical climate information and regional climate modeling.

Using historical climate information, the relationship between hydrologic variables of rainfall, streamflow, and water demand are being investigated by correlation and composite analysis. This exploratory analysis has employed several online climate investigation tools, particularly the interactive plotting and analysis tools of the Earth Systems Research Laboratory, Physical Science Division of NOAA. The goal of these analyses is to identify optimal climate indices for future forecasts of hydrologic variables in the Tampa Bay region.

We are carrying out high resolution (3km, 9km and 27km) regional climate modeling experiments using the MM5 model as part of this project. A significant portion of these regional climate simulations are being conducted using the University of Florida High Performance Computing Center. 20-years of daily rainfall and temperature are being simulated for the months of April, September, and December. Once complete, the results of these simulations will be statistically downscaled and their forecast skill evaluated in the Tampa Bay region. In conjunction with another project, the sensitivity of model results to land use change is also being investigated. (W. Graham, J. Jones, C. Martinez, S. Hwang, S. Risko)

Activity 3.3: ***Use of intra-seasonal and seasonal forecasts to reduce risk in regional public water supply management***

Over the past several months we have begun evaluating 1-14 day "reforecasts" developed by NOAA in short-term hydrologic forecasts of Tampa Bay Water. Currently computer code provided by NOAA (via the reforecast webpage) is being adapted for use to generate gauge-specific forecasts using both analog and logistic regression techniques. Once adapted, daily and weekly forecasts will be adapted and forecasts showing skill in the region will be blended with climatological forecasts to provide 1-week to 1-month forecasts. (C. Martinez, G. Kiker, W. Graham, J. Jones, D. Boniche)

Activity 3.3: ***Land use change effects on climate conditions in West-Central Florida***

High resolution (3km, 9km and 27km) regional climate modeling experiments are being conducted using the MM5 model. Significant changes in land use coverage in Tampa and the surrounding areas have occurred over the last decade (1995-2006). Our analysis show major transformation from agricultural, rangeland and upland forest categories to urbanization areas which are likely to impact environmental conditions. We are using sensitivity analysis to compare climate conditions from MM5 under default landuse maps and landuse scenarios where agricultural areas are replaced by urban areas and vice versa. The purpose of this work is to study changes in land-air energy exchange and lower atmosphere circulation. (J. Hernandez, G. Baigorria, S. Hwang, J. Jones, W. Graham)

***Activity 3.4*: Factors Influencing the Incorporation of Climate into Water Resource Management in Florida.**

Stakeholder driven integrated assessment tools, have been used to link hydro-climate research to water resource management. Though there are a number of case studies where these tools have been tested, the use of integrated assessments in resource management and in policy making is still not understood. This is especially true for hydro-climate research where improvements from large-scale research programs have not translated into changes in water resource management or policy. A contextual understanding of the complex regional factors that influence the integration of climate information into resource management may provide insight into this issue area. This thesis presents an analysis of the complex socio-political factors affecting the incorporation of climate in water resource management in Florida.

Activity 3.5 Identification of Stakeholder Needs

Following the initial survey of water managers undertaken last year, approximately 15 additional stakeholders were identified through contacts with the initial survey respondents. These stakeholders were queried using the previously developed survey to ascertain additional data needs for use by water managers and other stakeholders. Results from these additional surveys did not identify substantial additional data needs from the stakeholder groups. The newly surveyed groups also emphasized the need for training their group members to use available climate data more effectively, particularly in how to interpret longer-term climate predictions.

A follow-up telephone survey was also conducted with a number of last year's stakeholder groups to help refine their stated needs for water data. Several of them, in particular the US Army Corps of Engineers, requested information on longer term climate variability and climate change to allow them to more effectively communicate with their constituent groups on long-term temperature and precipitation variations. They are also undertaking studies on reallocation of water resources for floods and drought in the large reservoirs and need estimates of the effects of climate change on planning for distribution of future water reserves.

Several other groups and individuals who are doing similar surveys of water managers were identified over the course of the year. These include Chris Martinez (University of Florida), Tatiana Borisova (University of Florida), and Nathan Engle (University of Michigan). The survey used last year and this year was circulated to these scientists and discussed briefly via email. Some alternate wording was evaluated but no final changes were made. It was agreed that we need to continue working together in 2009 to hone the survey further, as well as develop alternate forms specialized for different stakeholder groups.

Activity 3.6 Website development for water managers needs

After the initial content for the web site was determined, a work server was identified at the University of Georgia in the Biological and Agricultural Engineering Department cluster of computers. A template for the home page was developed in cooperation with Brent Ferraro (University of Florida) which parallels the home pages for AgroClimate (agroclimate.org) and the Southeast Climate Consortium (seclimate.org).
Additional web pages were developed for the climate outlook and water outlook, including information for precipitation and temperature impacts on water supplies, evaporation potential, and flood and drought outlooks. These pages were prepared in conjunction with

AgroClimate.org to make sure that a unified message on El Nino phase was provided to all users. These template web pages were reviewed by Chris Martinez and other members of the Water Resources group and an initial view of the pages was provided for discussion at the annual meeting. The web page is continuing to evolve as additional links and data needs are identified and software problems are resolved.

Activity 3.7: Development of improved Lawn and Garden Moisture Index (LGMI)

Drought can develop on a relatively short time scale in lawn and agricultural systems, so UAH developed a Lawn and Garden Moisture Index based on high-resolution radar derived precipitation data. In order to retain the high spatial resolution and daily updates, we are testing the incorporation of insolation measured NOAA geostationary satellites. We were successfully in tests of scripts to access the GOES data for ingestion into DSSAT crop models and are now ready for a real-time test during the 2009 growing season.

Objective 4: To develop new and improved methods for integrating models from different disciplines for application of climate forecast information in agricultural and water resource decision making.

Activity 4.1. Exploring associations between Water Deficit Index and the yields of different crops

Our hypothesis was that an agricultural drought index can be used to predict yield loss due to drought; so the performance of a drought index can be evaluated based on the accuracy of the index to make yield predictions. The purpose of this study was to test this hypothesis as well as to evaluate a recently developed agricultural drought index, ARID, by comparing actual yields with the index-predicted yields through exploring a relationship between ARID and crop yields.

First, the relationship between crop yields and ARID was derived that accounts for the stage-specific sensitivity of a crop to water stress:

$$\hat{Y} = \overline{Y}_L \left[Y'_P \prod_{i=1}^{n} (1 - ARID)_i^{\lambda_i} \right] \qquad [1]$$

Where, $\hat{Y}$ is predicted yield, $\overline{Y}_L$ is location-specific mean yield, Y_P is potential yield, Y'_P is relative potential yield ($Y_P/\overline{Y}_L$), 'i' is a crop stage, 'n' is the number of stages, λ_i is the sensitivity coefficient to water stress during the i'th stage, and $ARID_i$ is the average ARID for the i'th stage. Being generic, ARID is intended to have a general relationship. So, to avoid developing location-specific yield-ARID relationships, Y'_P and $\overline{Y}_L$ terms are used in Eqn. [1].

Then, rainfed maize yields, along with their planting and harvesting dates, and daily weather data for 10 years were collected for three locations in Georgia. The duration of maize season for each year and location was divided equally into 3 stages: initial, middle, and final. Using the weather data, daily values of ARID were computed for each year and location, which later were converted to the stage-level average values. Through regression, values for the coefficients in Eqn. [1] were estimated using the observed yields and average ARID values, thus producing the following relationship for predicting maize yield ($\hat{Y}$) from ARID:

$$\hat{Y} = \overline{Y}_L \left[1.14(1 - ARID)_{initial}^{-0.25} (1 - ARID)_{middle}^{0.31} (1 - ARID)_{final}^{0.18} \right] \quad [2]$$

Finally, using Eqn. [2], maize yields were estimated for the corresponding locations and years and compared with the actual yields (Figure 1). The values of Willmott d-index, RMSE, and percent error were 0.90, 1763, and 19, respectively, which give an impression that not only has ARID the potential to make yield predictions but also an agricultural drought index can be used to predict yield loss due to drought.

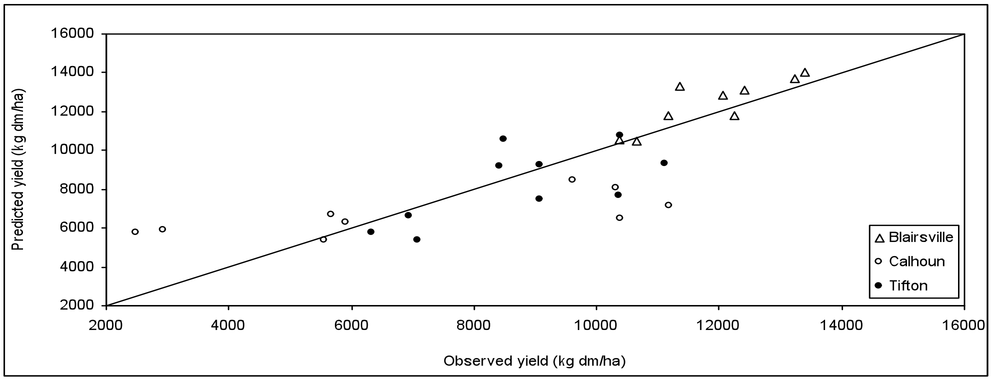

Figure 1 Comparing ARID-predicted and the observed maize yields for three locations in Georgia

Activity 4.2. Support development of regional drought information system for the southeast USA

The US NIDIS program is in the process of developing a pilot effort for the southeast USA that will help meet the needs for the region. K Ingram and N Breuer served as facilitators during a NIDIS workshop in June 2008. K Ingram also moderated a panel discussion for a NIDIS workshop held in Kansas City, MO. We will continue this support to NIDIS as well as the development of new drought monitoring and drought forecasting tools. K. Ingram, J. Jones

Activity 4.3. Reducing Drought Risks for Small Municipalities in the Southeast USA through Development of Municipal Water Deficit Index

The goal of the project, which is led by Auburn and has cooperators from UF and UGA, is to reduce drought risks for small- to mid-sized communities in the southeast. The specific objectives of the project are:

1. Identify key stakeholders, assess drought-related climate information needs of these communities, identify current and promising new policies for drought mitigation, and elicit data to refine hydrologic and economic modeling;
2. Quantify value of drought information, and evaluate cost-effectiveness of alternative policies for drought risk reduction; and
3. Develop municipal water deficit index (MWDI) and prototype visualization tool for disseminating drought information.

Objective 5. Foster effective use of climate information and predictions in forestry and wildfire management

Activity 5.1: Enhance the wildfire potential forecast system and extend to other forestry applications. (D. Zierden, G. Watry FSU).

In response to the wildfire threat forecast assessment, the KBDI forecast tool will be expanded and enhanced for greater utility. A tool will be developed that can display historical, current, or forecasted KBDI values for the Southeast in the same web interface. A KBDI real-time monitoring system will be established that utilizes high-resolution rainfall data such as the NWS stage III radar estimates. The forecast will also be expanded to all 12 months of the year, rather than just the wildfire season.

Objective 6: Document and assess the utility and impact of climate forecast information provided to stakeholders in agriculture and water resource management.

***Activity 6.1. Conduct outreach surveys and gather feedback from farmers, extension agents, and other climate information users* (Norman Breuer and Kenny Broad)**

How do we in the SECC know if we are actually helping anyone? We conduct assessment and evaluation to answer this question.

Norman Breuer assesses potential use of seasonal climate forecasts by different groups of potential users. He also undertakes case studies with particular groups of agricultural producers, including resource-limited or marginalized communities. An important step has been to assemble our baseline data on knowledge of climate variability, usefulness of forecasts, and potential adaptations in the states in which we operate.

Breuer works with Carla Roncoli of the University of Georgia to develop an Internet-based system for eliciting feedback from stakeholders. A survey embedded in the *AgroClimate* website provides real time feedback from end users. Comments and responses are regularly tabulated and analyzed to strengthen the SECC research and development effort.

Breuer continues to conduct open-ended, structured, personal interviews with extension agents and farmers with the aim of obtaining useful backwards flow information as a guide to producing more useful products. A learning community is has evolved from these continuous interactions, in which information flows both ways, with a view to constant cross fertilization in a framework of adaptive management, as follow-ups to Sondeos, and in pursuit of new lines of inquiry.

Activity 6.2: Training Workshops

We conducted a session on agricultural applications of climate information during the Annual Extension Winter Conference. We also conducted a workshop on AgroClimate decision support tools for county agents, as part of a program to increase awareness on the use of climate information and climate-based tools available to stakeholders. We were involved in various agent trainings, emphasizing the importance of climate forecasts in farm decisions and risk management. We also released climate and commodity outlooks during the past year.

Activity 6.3: Identification of end-users, understanding decision processes, and the role of climate forecasts

Minority farmers: The southeastern U.S. has experienced severe droughts during the last decade, which have resulted in significant losses in agriculture and restrictions to water use. These droughts have been devastating to farmers, but especially those without irrigation. Many minority farmers have been unable to invest in irrigation because of a lack of financial resources (including the inability to obtain loans because of racial discrimination). Additionally, they are rarely reached by conventional extension services because of the small-scale, part-time, diversified nature of their operations.

Based on the realization of the critical role that credible "boundary" institutions can play in mediating the interface between user groups and scientific knowledge centers, the SECC team has invested time and effort to develop institutional relationships with a Historically Black University (Fort Valley State University) and a civil right organization comprised of farmers' cooperatives (the Federation of Southern Cooperatives). Fort Valley State University has a network of extension agents that work specifically with minority farmers and a range of programs directed to improving the productivity and profitability of their agricultural operations. The Federation is composed of over 100 farmer cooperatives located in the southern United States actively engaged in trainings and interventions aimed at preserving the viability of African American rural communities. Several consultative meetings were held with representatives of these groups to discuss minority farmers' needs and capabilities with respect to climate information services. In collaboration with these partners, a research design was developed for an assessment of the specific vulnerabilities, risk management strategies, and information needs of African American farmers in Georgia.

In addition, the SECC team held exhibits and *Agroclimate* demonstrations at events targeted at minority farmers, including the Federation of Southern Cooperatives' Regional Meeting in Albany, Georgia on February 8-9, 2008 and Annual Meeting in Epes, Alabama on August 14-16, 2008. These interactions offered opportunities to elicit information on potential uses of climate information and tools such as those offered thru *Agroclimate* and users' feedback on what content, format, and language best fits the needs and capabilities of minority farmers.

Organic producers: Although it is comparatively small in acreage, organic production is the fastest growing agricultural sector in Georgia. Organic farmers include highly educated and computer literate individuals, some of whom are new to farming. Therefore, they represent a population who is well-positioned and highly motivated to use climate-based decision support tools, such as *Agroclimate*.

The SECC assessment team participated in several interactions with this community at key events, including an exhibit at the Georgia Organics' Annual Conference in Dalton, Georgia (February 28-March 2, 2008). There were over 600 people in attendance, a 30% increase over the previous year, and up to 1,000 participants are expected for the 2009 Annual Conference, which features prominent author Michael Pollen as keynote speaker. Drs. Roncoli and Furman were asked by Georgia Organics to help them organize a workshop on climate risk management and decision support tools to be included in the 2009 Annual Conference program. The session includes a diverse panel of experts from agriculture, climate, and social sciences, including SECC researchers.

As a parallel activity, Dr. Furman has started reviewing and analyzing organic and sustainable agriculture blogs to better understand how organic farmers perceive and discuss issues related to climate change adaptation and mitigation. The findings will help the SECC team to formulate messages that are consistent with users' cognitive and linguistic framing of climate risk.

Activity 6.4: Evaluating AgroClimate tools for their potential and actual uses and impact

<u>Data analysis and write-up of farmer interviews in South Georgia:</u> Between January to March 2007, Drs. Roncoli and Crane conducted semi-structured interviews with 38 farmers in 20 counties, representing a broad cross-section of production systems found in Georgia. The objective of these interviews was to examine farmers' decision-making processes, to identify how climate variability factors into them, and to identify which decisions were or may be influenced by forecasts. The research also elicited farmers' views on what climate parameters are most useful and what communication modes are most effective to reach them. Interviews were fully transcribed and entered into qualitative data analysis software (NVIVO).

In 2008 the team focused on data analysis and writing up. The outcome is an article submitted to the AMS journal Weather, Climate, and Society, as well as numerous poster and oral presentations.

Activity 6.5: Assessing the accessibility, relevance, utility of AgroClimate tools from end-users' point of view

<u>Media representations of ENSO</u>: In 2008, a study was conducted of newspaper articles on El Nino and/or La Nina impacts in the Southeast U.S. The study aimed to understand how ENSO and ENSO-based forecasts are represented in media available to agricultural producers and natural resource managers. The study is based on analysis of 78 articles, including 14 articles from the Southeast Farm Press (a regional newspaper directed to agricultural producers; 25 articles from urban newspapers (the Atlanta Journal & Constitution and the Augusta Chronicle); and 39 articles from small town newspapers in Georgia published between 2005 and 2008 (period of active SECC outreach). The articles were entered in software for analysis of qualitative data (NVIVO) and quantitative data (EXCEL) by 1 coder and 3 verifiers, and were analyzed for 74 parameters relative to the nature and effects of ENSO, seasonal climate forecasts, sources of authoritative knowledge, public and private responses, references to climate change, etc. The analysis shows that :

- Newspaper readers in Georgia are routinely exposed to some information about ENSO, but the scientific knowledge is not always represented clearly, correctly, or completely.
- The SECC is often cited as an authoritative source, but its ENSO-based climate forecasts are not conveyed in ways that support integration into management decisions

The findings were subject of poster presentation and are being written up in an article to be submitted to a scientific journal.

<u>KBDI assessment:</u> In May 2008, Drs. Roncoli and Breuer carried out 12 phone interviews to follow up the assessment of the KBDI wildfire threat forecast assessment originally conducted in May-June 2006. These interviews identified additional potential barriers to the incorporation of such tool into forest and fire management decisions, including

- Technical factors: The KBDI index tends to “break down” during the dry season, when a light rain can reduce the index by moistening the top layer of duff and soil, inducing fire managers to lower their guard.
- Communication factors: Fire managers are unfamiliar with *Agroclimate* and prefer using “one-stop shop” portals for climate information, such as those of the Georgia Forestry Commission and Florida Division of Forestry (but these portals do not link to the SECC forecast).
- Institutional factors: Regionally specific conditions of fire management in GA and FL have shaped unique institutional cultures (Georgia has a more decentralized system, with greater emphasis on human judgment and field experience; Florida has a more centralized system, which relies mostly on advanced technology): this affects the ability of fire managers to additional tools into their decisions. Private operators may be more inclined than public sector managers to integrate different information sources and long-range planning into management decisions.

<u>Climate Change Fact Sheet</u>: The assessment team contributed to writing and design of “*Climate Change Basics for the Southeast U.S.*”, a fact sheet summarizing the state-of-the-art of the science concerning climate change impacts in the region, for distribution to agricultural extension agents and other stakeholders, in response to their requests.

Activity 6.6: Assessing stakeholders interests and needs for climate change information

While there is much information available about global climate change, there is far less information available on the probably local impacts of climate change. Rational adaptation strategies require local or regional information. Moreover, the stakeholders for climate change information appear to come from many more sectors than the agricultural and water resource managers that the SECC has targeted to date. In this activity, we will focus on the needs for climate information and tools for local governments, business, such as environmental engineering firms, as well as agricultural stakeholders.

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Kiker, G.A. and Jagganathan, S. Development of a management-focused, spatial decision support tool to simulate water resource effects of climate forecasting within southern Florida beef cattle agroecosystems. Presented at the University of Florida Water Institute Symposium, February 27-28, 2008.

Martinez, C.J., Newman, M.A., Jones, J.W., and W.D. Graham. Coupled modes of variability between Pacific and Atlantic sea surface temperatures and monthly precipitation in southwest Florida. Presented at the American Geophysical Union Fall Meeting. San Francisco, California, December 10-14, 2007.

Martinez, C.J., Newman, M.A., Jones, J.W., and W.D. Graham. Relationships between Pacific and Atlantic sea surface temperatures and monthly precipitation in southwest Florida. Presented at the NOAA 32nd Annual Climate Diagnostics and Prediction Workshop. Tallahassee, Florida, October 22 – 26, 2007.

Martinez, C.J., Jones, J.W. and W.D. Graham. Tampa Bay Water: Use of climate forecasts to reduce risks in regional water supply management. Presented at the Southeast Climate Consortium Program Review, May 14-16, 2007.

Martinez, C.J., Baigorria, G.A., and J.W. Jones. Influence of climate variability on corn production in the southeast USA. Presented at the Southeast Climate Consortium Program Review, May 14-16, 2007.

Peres, N. A., Fraisse, C. W. 2007. Development of a disease forecast system for strawberries as a tool on AgClimate. Southeast Climate Consortium (SECC) Program Review Meeting. May 14-16, 2007. Griffin, GA.

Royce, F., G.A. Baigorria, H. Hu, C. Fraisse, and T. Pathak. ENSO classification and summer crop yields in the Southeastern USA. Workshop on climate change impacts and adaptation to agriculture, forestry and fisheries at the national and regional levels. WMO/South East Climate Consortium. Orlando, FL. November 18-21, 2008. Poster presentation.

Romero, C.C. and G.A. Baigorria. The effect of temperature on sweetpotato growth and development. In: Proceedings of the International Annual Meeting of ASA/CSSA/SSSA/GSA/GCAGS/HGS. Houston, TX. October 5-9, 2008. Session 534-201. Poster presentation.

Romero, C.C., M.D. Dukes, G.A. Baigorria, and R. Cohen. Using climate information to determine irrigation requirements for citrus in Florida. In: Proceedings of the Climate Information for Management Risk (CIRM). St. Pete Beach, FL. June 9-15, 2008. Session: Extension and Application of Climate Information for Agriculture and Natural Resources. Poster presentation.

Shin, D.W., S. Cocke, Y-K. Lim, T.E. LaRow, G.A. Baigorria, and J.J. O'Brien. Probabilistic crop yield simulations over the Southeast US using global and regional climate model products. In: Proceedings of the Climate Information for Management Risk (CIRM). St. Pete Beach, FL. June 9-15, 2008. Session: Impacts of Climate Variability and Climate Change on Agriculture and Natural Resources. Poster presentation.

Russo, S.E., E. Rivero, Romero, C.C., and G.A. Baigorria. Uncertainties in the Argentinean wheat production due to climatic change scenarios. In: Proceedings of the Climate Information for Management Risk (CIRM). St. Pete Beach, FL. June 9-15, 2008. Session: Impacts of Climate Variability and Climate Change on Agriculture and Natural Resources. Poster presentation.

Shin, D.W., S. Cocke, T.W. LaRow, Y.-K. Lim, G.A. Baigorria, and J.J. O'Brien. Interannual crop yield simulations over the southeast US using a regional climate model. In: Proceedings

of the 28th Conference on Agricultural and Forest Meteorology. Orlando, FL. April 28th – May 2nd, 2008. Session 9: Atmospheric Modeling and Data Assimilation of Land-Surface Climate Interactions. Oral presentation.

Pathak, T.B., J.W. Jones, C.W. Fraisse. Use of Climate Indices in Cotton Yield Risk Assessment for Southeastern USA. Presented as International Annual Joint Meeting ASA-CSAA-SSSA. October 5 – 9, 2008. Houston, TX.

Pathak, T.B., J.W. Jones, C.W. Fraisse. Use of Climate Indices to Assess Cotton Yield Risk in Southeastern U.S.A. Presented at International symposium Climate Information for Managing Risk (CIMR), June 10 – 13, 2008. St. Pete Beach, FL.

Outreach Activities

Fraisse, C. W., D. Zierden. 2007. AgClimate hands on workshop. Tropical Research & Education Center, January 9, 2007. Homestead, FL.

Fraisse, C. W., D. Zierden, N. A. Peres, J. Jackson. 2007. Climate forecasting applications to agriculture and natural resources. IFAS Extension Symposium, May 10, 2007. Gainesville, FL.

Fraisse, C. W. 2007. Climate Forecasting and Decision Making in Agriculture. AgriTech - Strawberry Growers Association. August 28-29, 2007. Plant City, FL.

Fraisse, C. W. 2007. Climate change: What does it mean to agriculture? Florida Pecan Field Day. September 6, 2007. Monticello, FL

Fraisse, C. W. 2007. AgClimate Workshop. Bernallio Cooperative Extension Office, December 3, 2007. Albuquerque, NM.

Fraisse, C. W. 2007. La Niña outlook for the West central Florida horticultural industry. Winter Weather School, December 4, 2007. Dade City (Pasco County), FL.

Fraisse, C. W. 2007. Low carbon economy: Opportunities for producers in the Southeast. Madison County Beef Cattlemen’s Association, December 13, 2007. Madison, FL.